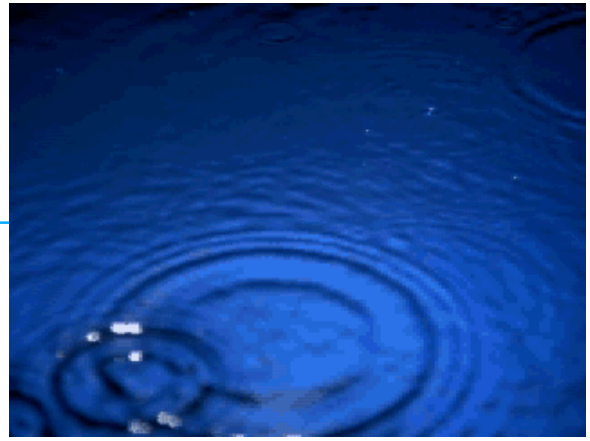
GPM

GLOBAL PRECIPITATION MEASUREMENT

Global Precipitation Measurement

System Definition Review

System Architecture



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December 6-8, 2005

Outline

- ***Changes Since SRR***
- ***Architecture Overview***
  - *Mission Architecture*
  - *Product Breakdown Structure*
  - *Core Spacecraft*
  - *Constellation Spacecraft*
  - *DPR*
  - *GMI*
  - *Technical Resource Budget Summary*
  - *Trade Studies*
- ***Operations Concept***
- ***Risks***
- ***Upcoming/continuing Trades***
- ***Backup***

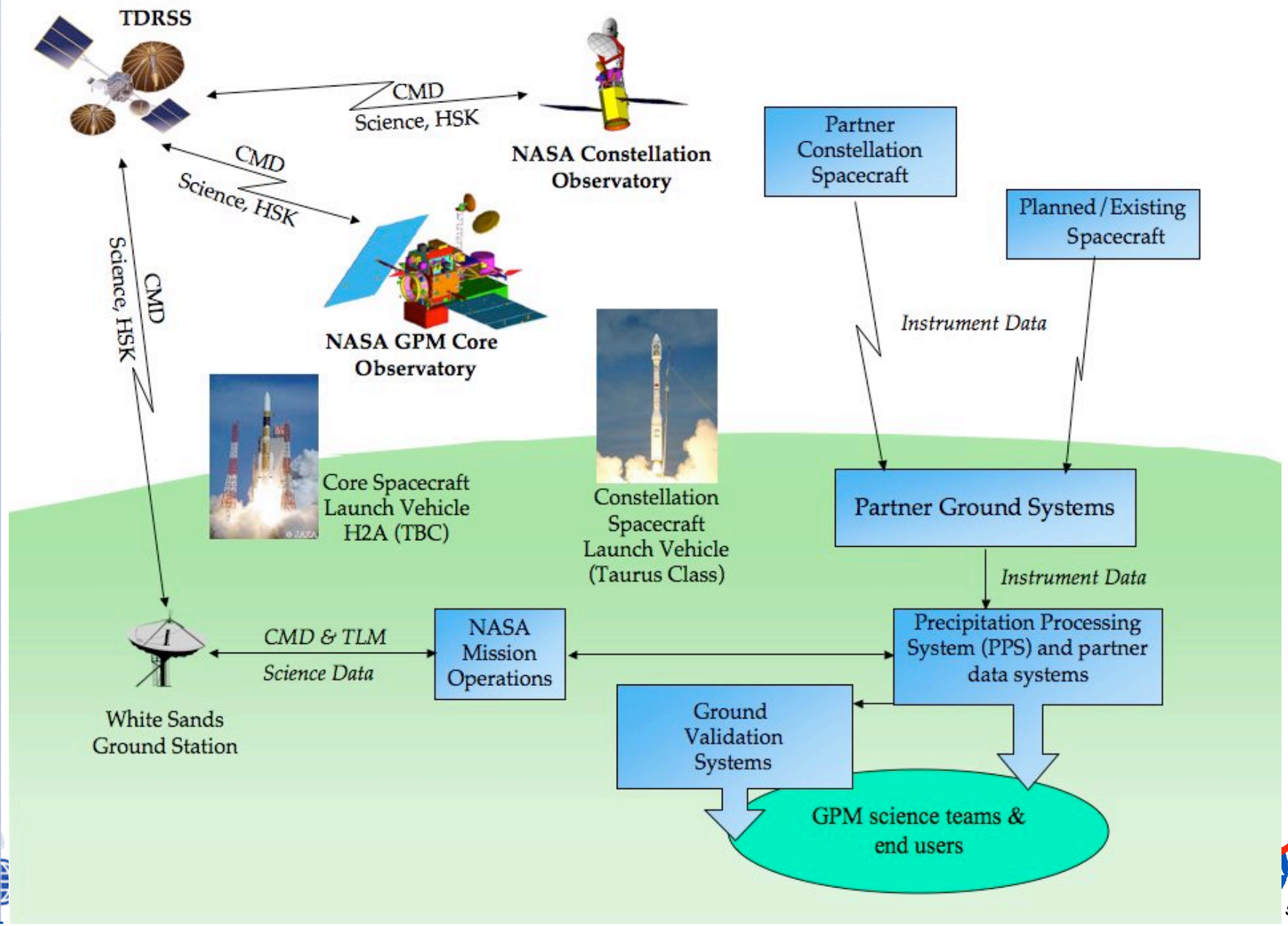
Changes Since SRR

- ***Spacecraft Acquisition changed from in-house to out-of-house to "hybrid"***
- ***Instrument of Opportunity (IOO) has been deleted***
- ***Core Spacecraft no longer co-manifested with GOSAT***
  - *Due to schedule divergence with GOSAT*
- ***Deleted Internet-in-Space***
  - *Due to acquisition strategy using "off-the-shelf" RSDO components*
- ***Autonomous orbit maintenance has been eliminated***
  - *New development under RSDO procurement*
  - *Orbit maintenance frequency 1x/week based on new Schatten predicts*
- ***Ball Aerospace selected as GMI developer***
  - *Option for High frequency channels has been exercised*

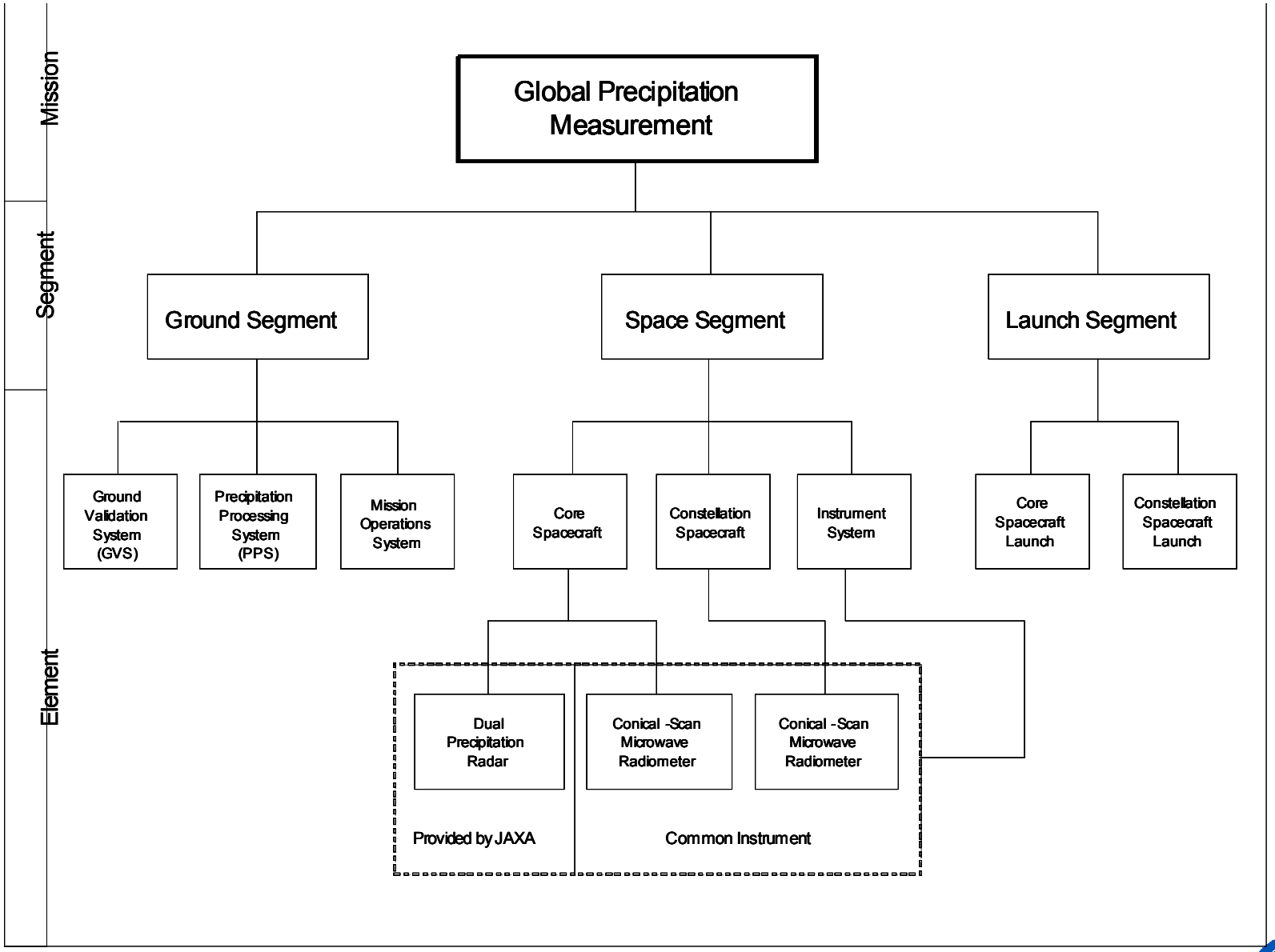
Driving Level 1 Requirements

- ***(3.1.1.2) Precipitation sampling - Global coverage with 3 hour revisit times***
  - *Constellation of satellites, drives orbit definitions for NASA-provided assets*
  - *Ingest multiple data streams from NASA and domestic and foreign partners*
- ***(3.1.1.1) Precipitation Measurement***
  - *Drop size distribution (DSD) measurement*
    - *Drives use of dual-frequency precipitation radar (DPR)*
    - *Drives co-alignment requirements*
- ***(3.1.1.3) Swath Data Latency - 3 hours***
  - *All data to the ground within 90 minutes*
- ***(3.1.1.8) Ground Based Measurements***
  - *Ground-based measurements for satellite algorithm improvement*
- ***(3.1.1.6) Calibration Standard***
  - *DPR/GMI provide the reference for other PMRs in the constellation*
    - *Drives geo-location requirement*
- ***(3.1.2.1) Core Observatory Lifetime: 3 years, Overlap with Constellation of 18 months***
  - *Consumables sized for 5 yrs*
- ***(3.1.2.3) Reliability requirement is 0.7 for return of instrument data***
- ***(2.2) Risk Classification:*** Class B mission per NPR 8705.4
- ***(3.1.2.6) End-of-Life disposal***
  - *Design-for-demise*

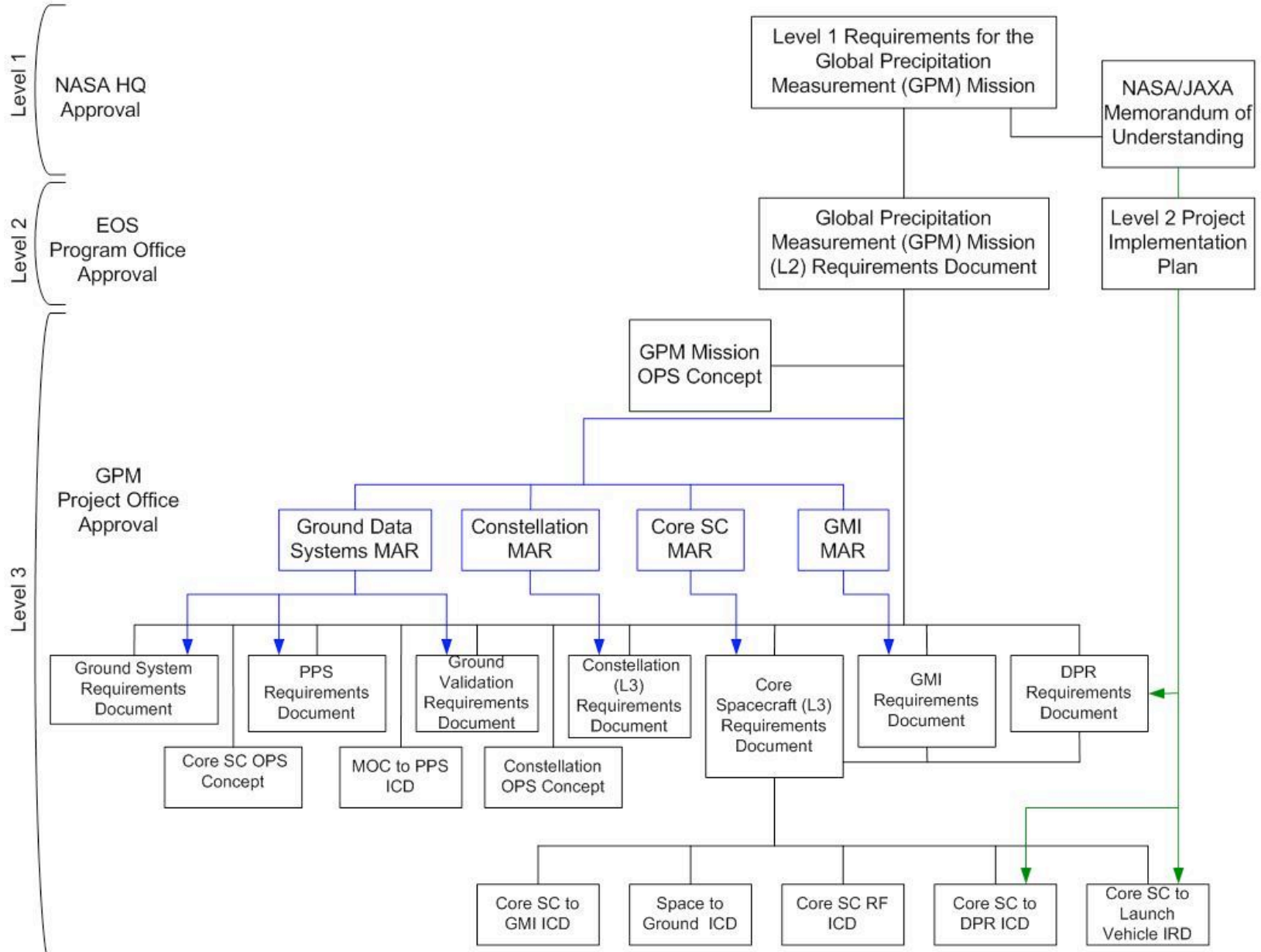
GPM Mission Architecture Overview



GPM Architecture Hierarchy

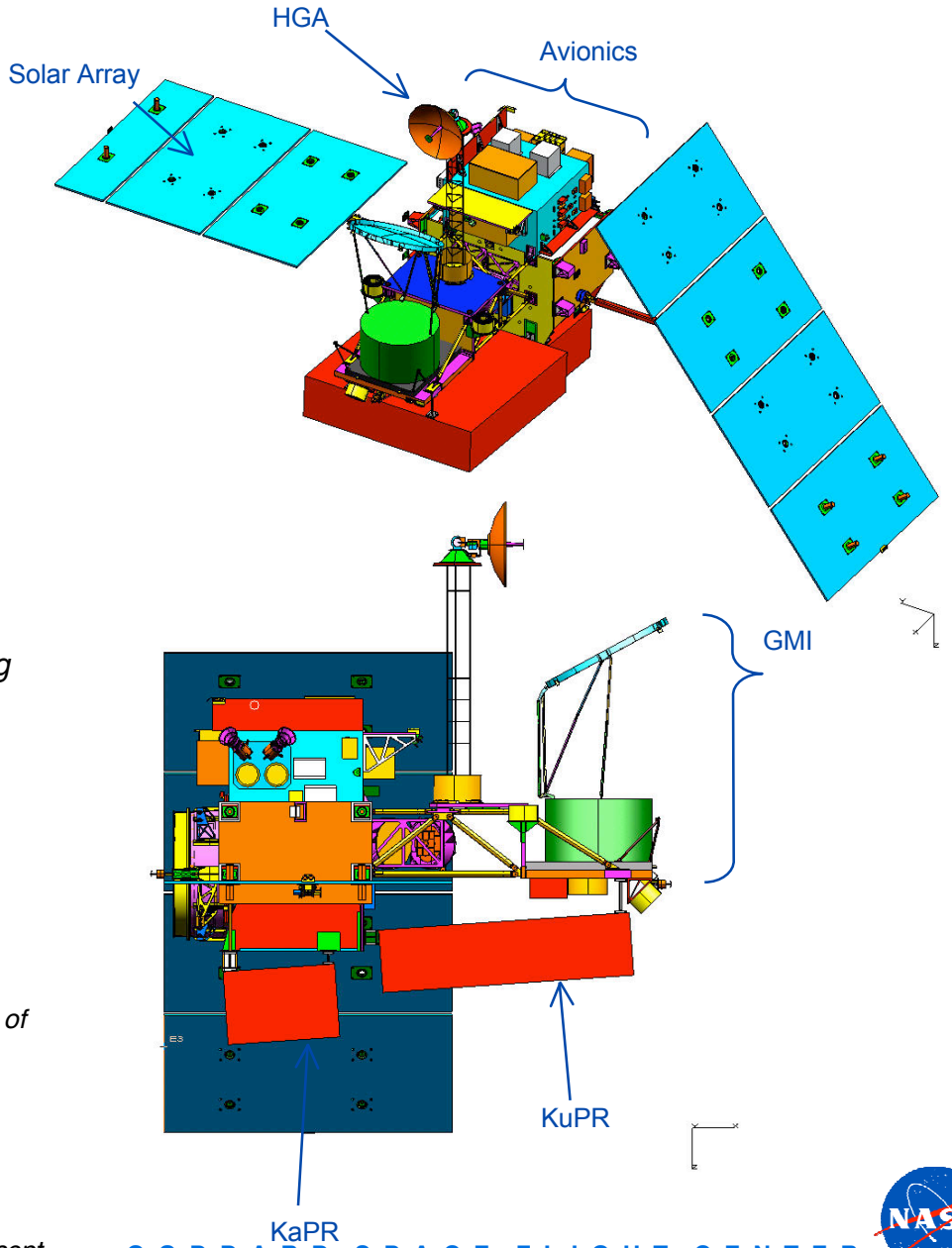


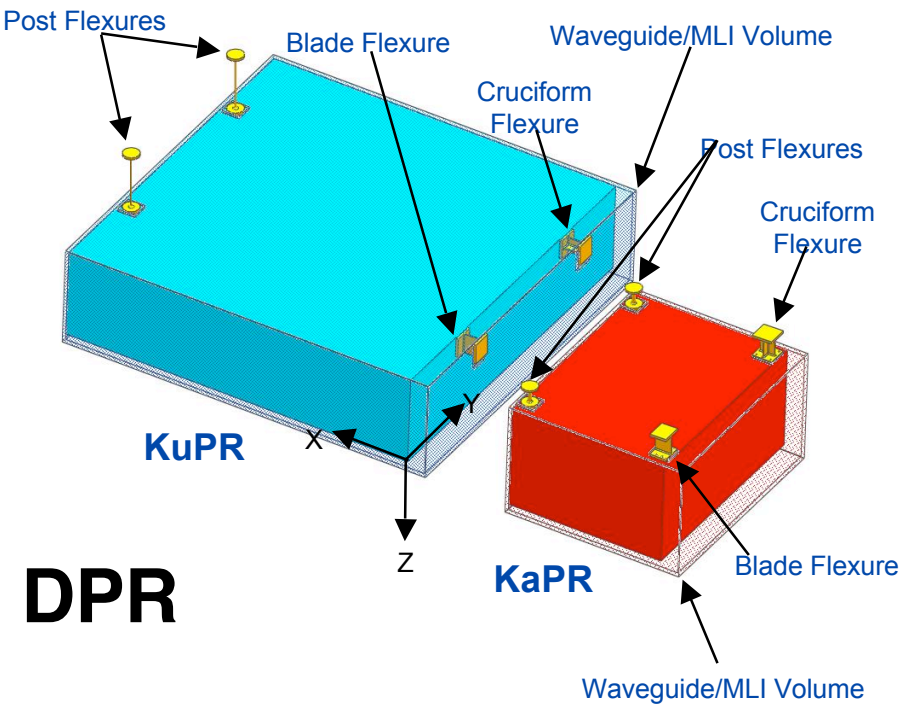
Requirements Doc Tree



Core Spacecraft

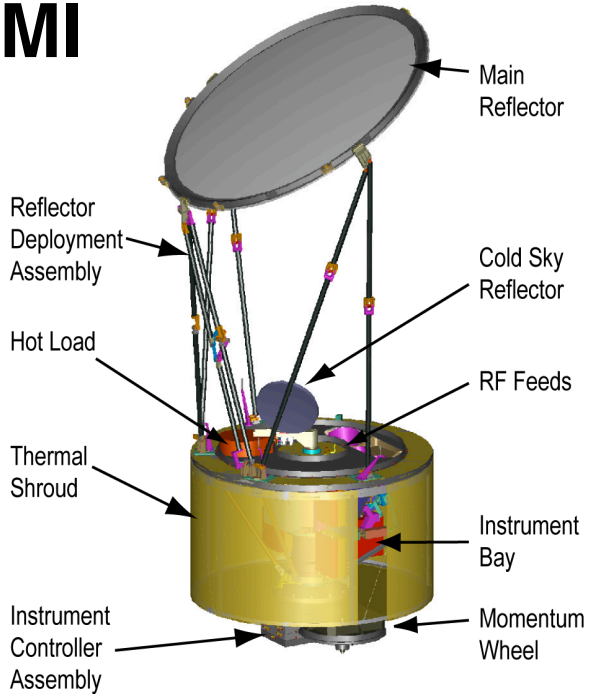
- ***Orbit Parameters***
  - *Injection Orbit: 400 km x 650 km*
  - *Final Orbit: 407 +/- 1 km circular*
  - *Inclination: 65 Degrees*
  - *Periodic yaw maneuver at Beta = 0 degrees*
- ***Observatory***
  - *Mass Allocation 3200 kg*
  - *Power (oap, W) 1950W*
  - *Data Rate 300 kbps continuous*
- ***Spacecraft Bus***
  - *3-axis stabilized, nadir pointing*
  - *Single Axis Articulating Solar Arrays*
  - *Two Axis Gimbal High Gain Antenna Pointing System*
  - *Propulsion System for Orbit Maintenance*
- ***Instruments***
  - *Dual-frequency Precipitation Radars (DPR)*
    - *Ku Band Radar (KuPR) similar to TRMM PR*
    - *Ka Band Radar (KaPR) new design*
  - *GPM Microwave Imager (GMI)*
    - *Passive Microwave Radiometer (Larger version of TRMM Microwave Imager)*





DPR

GMI

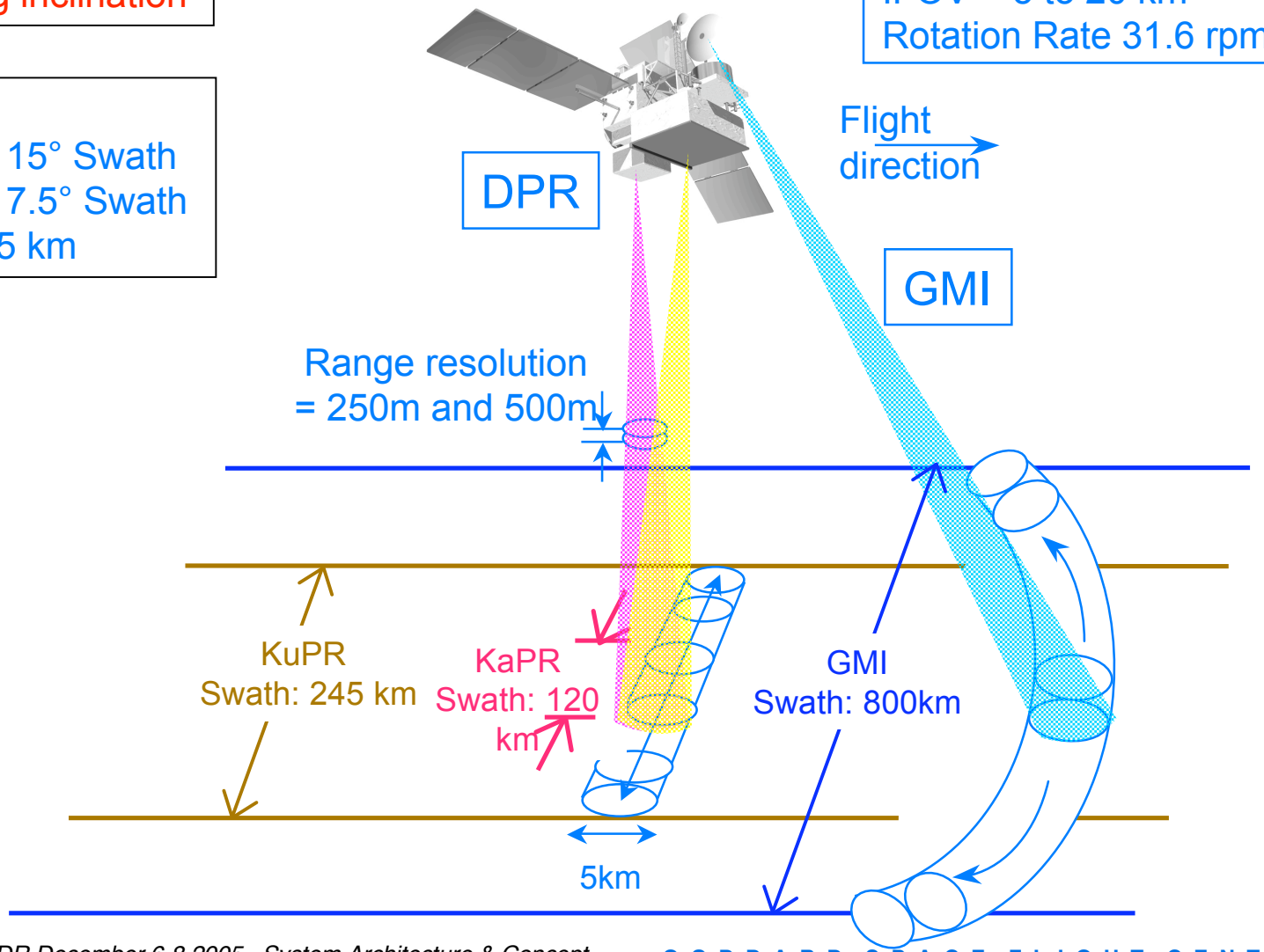


	KuPR	KaPr	GMI
Type	148 Element Active Phased Array	148 Element Active Phased Array	Passive Microwave Radiometer
Frequency	13.6 GHz	35.5 GHz	10.65 to 183.3 GHz (13 channels)
Horiz. Resolution	5 km	5 km	approx. 32 to 4.4 km
Mass	450 kg	330 kg	125 kg
Volume	2.4mx2.4mx0.6m	1.44mx1.07mx0.7m	1.22m Antenna dia.
Power	384 W	326 W	155 W
Data Rate	108.5 kbps	81.5 kbps	35 kbps

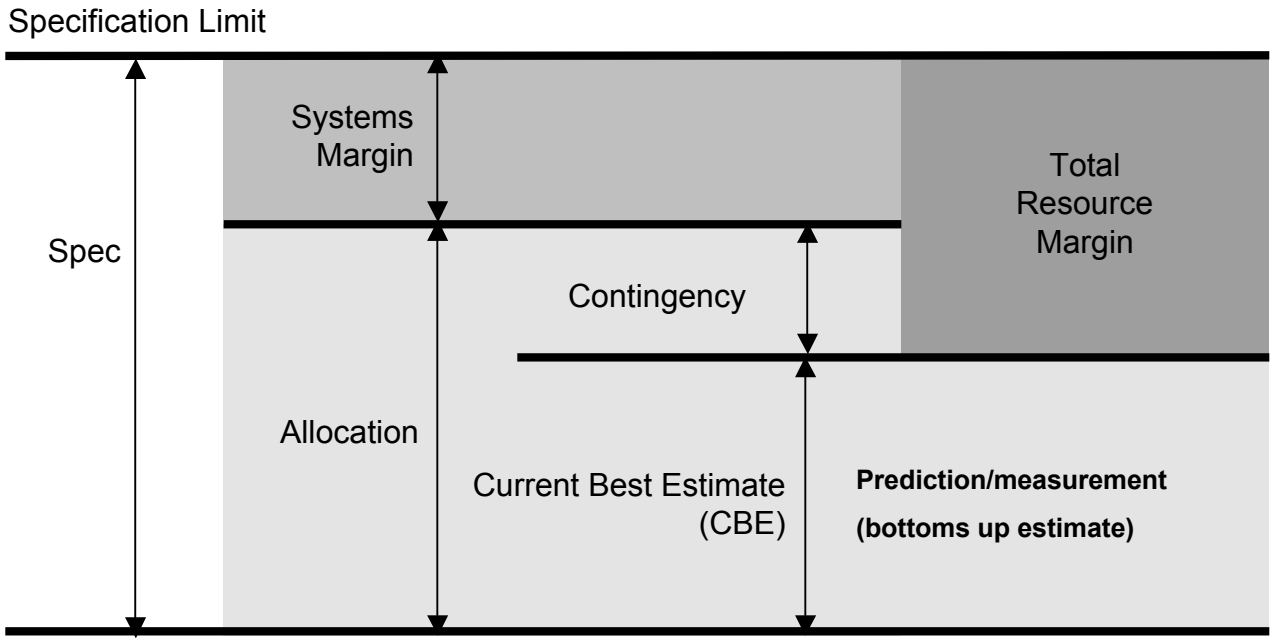
Orbit
~407 km altitude,
65 deg inclination

DPR
KuPR 15° Swath
KaPR 7.5° Swath
IFOV 5 km

GMI
Earth Incidence Angle 52.8°
IFOV ~ 5 to 20 km
Rotation Rate 31.6 rpm



Budgets - Margin Definition



KEY
Project Control
Subsystem / Instrument Control

Project to set Allocation and Margin

- *Margin to be held by Project*
- *Contingency to be held by Subsystem/Instrument*

Total Resource Margin Requirements

- *Total Resource Margin = Contingency + System Margin*

Technical Resource Margin Summary (1/2)

GPM Technical Resource Margin Summary

		Current Status			Time-Phased Margin Requirements				
Technical Resource	**Units**	**CBE**	**Allocation**	**Margin**	**@ PDR (Phase B)**	**@ CDR (Phase C)**	**@ Launch (Phase D)**	**Golden Rule**	**Comments**
Mass									
Observatory Dry Mass	Kg	2127.3	2720	27.9%	?20%	?15%	?0%	1.06	
GSFC Mass	Kg	924	1127						
RSDO Mass	Kg	348	380						
Instrument Mass	Kg	855	905						
Power (EOL Capacity)									
Hybrid Budget:									
Observatory Power	W	1571	1950	24.1%	?15%	?15%	?10%	1.06	
GSFC Power	W	230	250						
RSDO Power	W	542	600						
Instrument Power	W	799	865						
GSFC In-House Design:									
Solar Array Power*	W	4348	NA						â=0: 4348 W, â=90: 2571 W for nadir pointing, 5721 W safehold, 3 yr EOL
Battery Capacity*	A-hr	?140	NA						Based on Li-Ion, 30% max DOD w/one cell failure
Propellant	Kg	400	480	20.0%	3ó	3ó	3ó	1.06	
Telemetry & Command Hardware Channels		TBD	TBD	TBD	?15%	?10%	?0%	1.06	TBD Based on RSDO AP Design
RF Link*									
MA Return - HGA - Normal Ops	kbps		230	? 3 db	3 db	3 db	3 db	1.06	Normal Operations – DAS MA
MA Return - HGA - Contingency Ops	kbps		230	? 3 db	3 db	3 db	3 db	1.06	Contingency Ops - Legacy MA
MA Forward - HGA - Contingency Ops	kbps		64	? 3 db	3 db	3 db	3 db	1.06	Contingency Ops - Legacy MA
MA Return - Omni - Contingency Ops	kbps		4	0 db	3 db	3 db	3 db	1.06	Contingency Ops - Legacy MA, 0 db at output of Viterbi decoder
MA Forward - Omni - Contingency Ops	bps		350	2.43 db	3 db	3 db	3 db	1.06	Contingency Ops - Legacy MA
SSA Return - HGA - Normal Ops	Mbps		2.3	1.98 db	3 db	3 db	3 db	1.06	Normal Operations
SSA Forward - HGA - Normal Ops	kbps		64	? 3 db	3 db	3 db	3 db	1.06	Normal Operations
SSA Return - HGA - Contingency Ops	kbps		4	? 3 db	3 db	3 db	3 db	1.06	Contingency Operations
SSA Forward - HGA - Contingency Ops	kbps		2	? 3 db	3 db	3 db	3 db	1.06	Contingency Operations
SSA Return - Omni - Launch & Contingency Ops	kbps		4	? 3 db	3 db	3 db	3 db	1.06	Launch & Contingency Ops
SSA Forward - Omni - Launch & Contingency Ops	kbps		2	? 3 db	3 db	3 db	3 db	1.06	Launch & Contingency Ops
GN Downlink - Omni - Mission Contingency	Mbps		4	? 3 db	3 db	3 db	3 db	1.06	Mission Contingency
GN Uplink - Omni - Mission Contingency	kbps		64	? 3 db	3 db	3 db	3 db	1.06	Mission Contingency
GN Downlink - Omni - Contingency	kbps		4	? 3 db	3 db	3 db	3 db	1.06	Contingency Operations
GN Uplink - Omni - Contingency	kbps		2	? 3 db	3 db	3 db	3 db	1.06	Contingency Operations

* Based on 2004 GSFC In-House Design

Technical Resource Margin Summary (2/2)

GPM Technical Resource Margin Summary

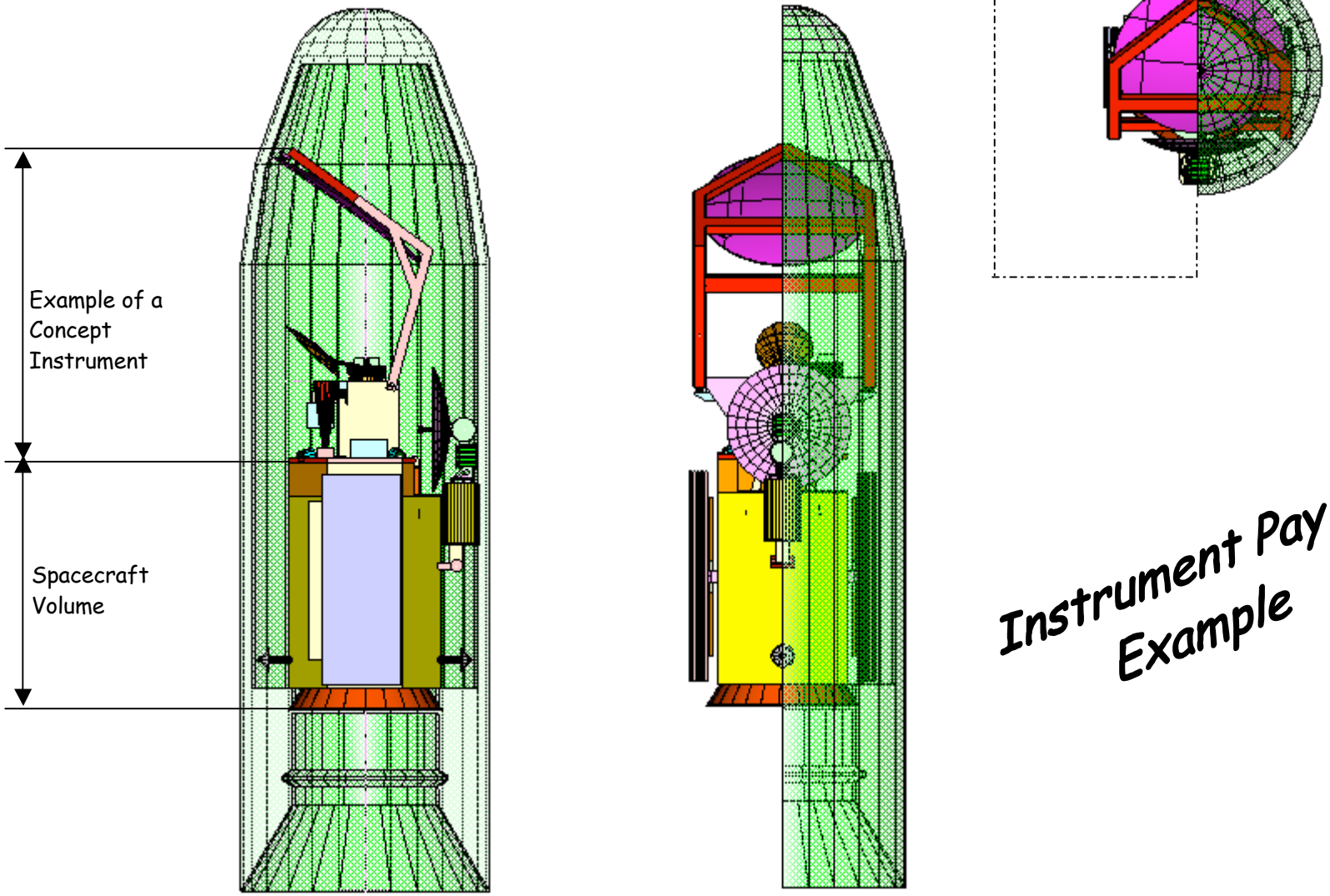
	Current Status				Time-Phased Margin Requirements				
Technical Resource	**Units**	**CBE**	**Allocation**	**Margin**	**@ PDR (Phase B)**	**@ CDR (Phase C)**	**@ Launch (Phase D)**	**Golden Rule**	**Comments**
Pointing									
KuPR/KaPR Co-Alignment (Pre-Launch)	arc-min	31.184	42.000	10.816				NA	Margin is in arc-min
KuPR/KaPR Co-Alignment (Post-Calibration)	arc-min	7.826	8.447	0.621				NA	Margin is in arc-min
DPR Geolocation Knowledge	arc-min	15.937	21.116	5.179				NA	Margin is in arc-min
DPR Pointing Accuracy	arc-min	35.570	42.200	6.630				NA	Margin is in arc-min
GMI Geolocation Knowledge	arc-min	11.100	11.400	0.300				NA	Margin is in arc-min
GMI Pointing Accuracy	arc-min	18.226	18.600	0.374				NA	Margin is in arc-min
Demise	m^2	4.4	8	81.8%				NA	
Flight Software:					Analysis	Analysis/ Measured	Measured		
Instrument 1553 Bus	kbps	229	552	25.0%	≥25 %	≥20%	≥10 %	3.07	margin calculation includes overhead
Spacecraft 1553 Bus	kbps	10	370	94.6%	≥25 %	≥20%	≥10 %	3.07	margin calculation includes overhead
Average CPU	TBD	TBD	TBD	TBD	≥50 %	≥40%	≥30 %	3.07	TBD Based on RSDO AP Design
CPU Deadlines	TBD	TBD	TBD	TBD	≥50 %	≥40%	≥30 %	3.07	TBD Based on RSDO AP Design
PROM	TBD	TBD	TBD	TBD	≥30 %	≥20%	≥0%	3.07	TBD Based on RSDO AP Design
EEPROM	TBD	TBD	TBD	TBD	≥50 %	≥40%	≥30 %	3.07	TBD Based on RSDO AP Design
RAM	TBD	TBD	TBD	TBD	≥50 %	≥40%	≥30 %	3.07	TBD Based on RSDO AP Design
PCI Bus	TBD	TBD	TBD	TBD	≥70 %	≥60%	≥50 %	3.07	TBD Based on RSDO AP Design

$$\text{Margin(in\_percent)} = \frac{(\text{Available\_Resource} - \text{Estimated\_Value\_of\_Resource})}{\text{Estimated\_Resource}} \times 100$$

GPM Constellation Spacecraft

- ***Launch Date - within 18 months of Core Spacecraft***
- ***Spacecraft bus:***
  - *Rapid Spacecraft Development Office (RSDO)*
- ***Instrument:***
  - *GPM Microwave Imager (GMI) duplicate instrument*
    - *Adjustment to maintain Earth Incidence Angle*
- ***Operations***
  - *Uses TDRSS-MA continuously for GMI Science/HSK & SC HSK*
- ***Integrated Mission Design Center (IMDC) studies***
  - *July 2000 using In-house Synthetically Thinned Aperture Radiometer (STAR)*
  - *August 2001 using GMI-type radiometer*
  - *Plan for April 2006 with the Ball Aerospace GMI radiometer*
- ***Orbit studies to optimize global coverage ongoing***

Launch Configuration - Taurus 2110



Instrument Payload Example

Orbit Studies

- ***Constellation orbit analysis***
  - *Average Revisit Time*
- ***Core orbit analysis***
  - *Drag make-up*
  - *Time to cover total area*
  - *Selected 65°, 407 km*

Average Revisit Time

- ***Requirement***
  - *(L2: 3.1.8)GPM shall measure precipitation rates with an average revisit time of 3 hours or less over 80% of the globe*
  - *Optimize a spacecraft constellation to maximize the retrieval of science data*

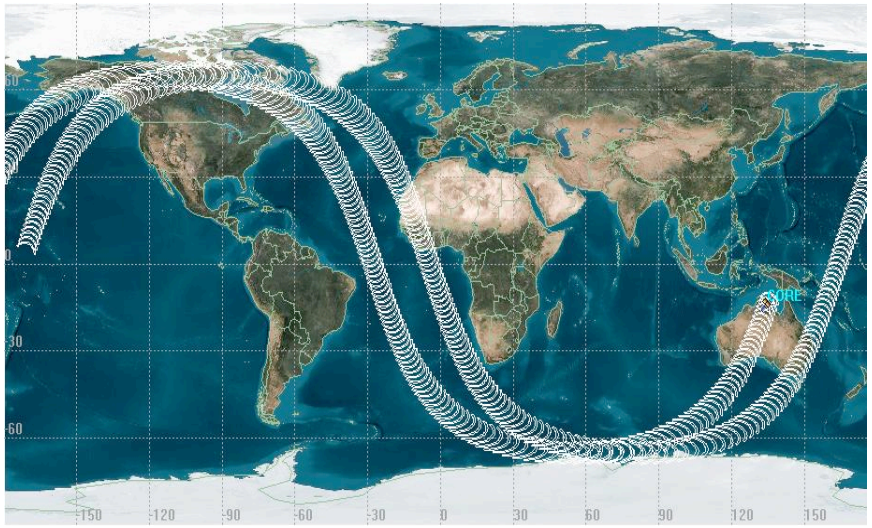
- ***Assumptions***
  - *Use a mixed constellation of spacecraft :*
    - *Fixed Spacecraft : already or soon-to-be launched satellites with suitable instruments for rainfall measurement designed for different mission than GPM*
    - *Variable Spacecraft : dedicated GPM satellites designed to best complement the fixed spacecraft for GPM purpose*
  - *GPM dedicated satellites are divided in two categories:*
    - *Core spacecraft (GPM-Core)*
    - *constellation spacecraft (NASA-1)*
  - *Challenges: Since the fixed spacecraft all have different orbital elements, instruments, and groundtracks which cannot be changed for GPM purpose, the two major challenges are:*
    - *Finding the **best placement for the variable spacecraft** so that the science requirements are satisfied*
    - *Insuring **long term stability** (i.e., yearly evolution of the index performance)*

Possible GPM Constellation

- ***Fixed Spacecraft:***
  - *US Assets: DMSP F-17, 18 & 19, NPOESS-13:30, NPOESS-17:30, NPOESS-21:30*
  - *Foreign Assets: GCOM-W, E-GPM, Megha-Tropiques*
- ***Variable Spacecraft:***
  - *GPM-Core*
  - *NASA-1 (GPM constellation spacecraft)*
    - *600 km orbit, a = 6978 km, e = TBD, i = TBD , Ω = TBD*

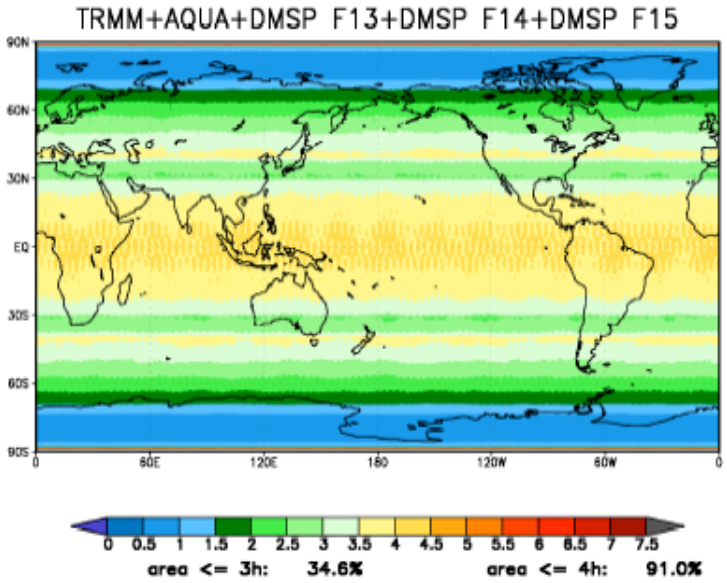
Figure-of-Merit: 3-Hr Coverage

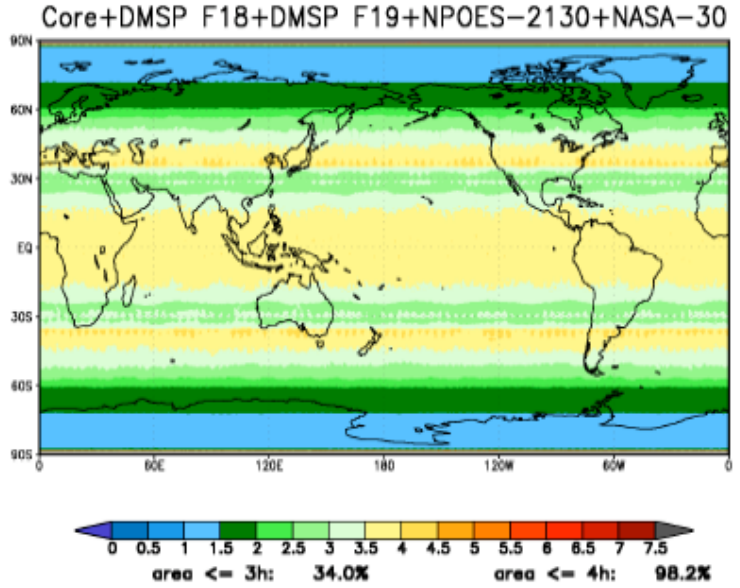
- ***GPM Core***

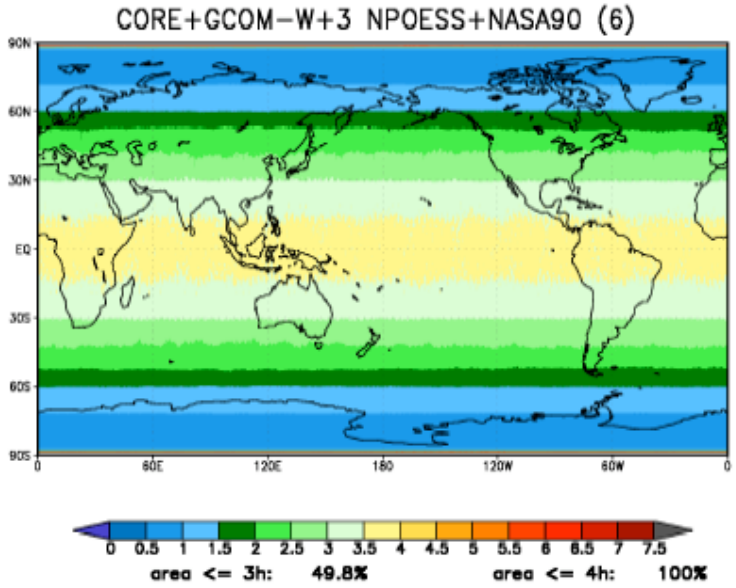


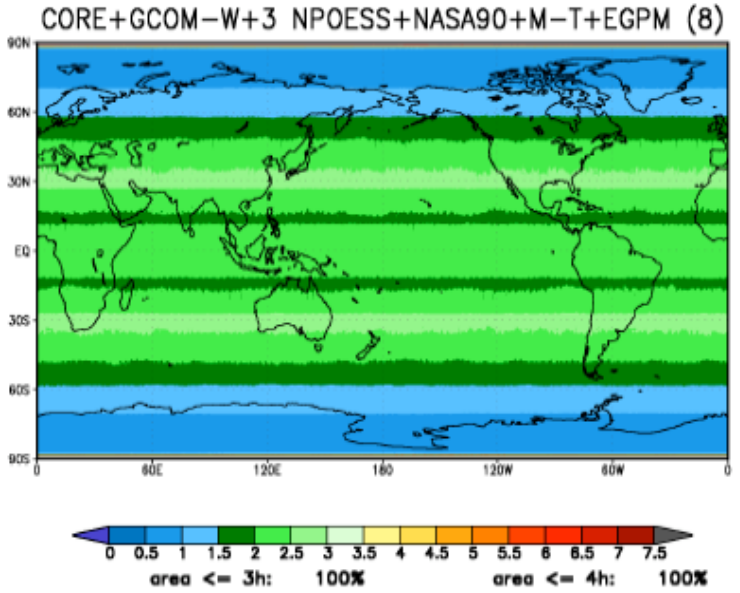
- ***Core, GCOM-W, NASA-1, EGPM, NPOESS-1330, NPOESS-1730, NPOESS-2130, Megha-Tropiques***

Average Revisit Statistics









GPM-Core: Reference Orbit and Maintenance

- ***Requirements***
  - *(L2: 5.5)GPM Core Geodetic Altitude within [397 km, 419km] for the mission lifetime*
  - *Study Orbit Maintenance Fuel and Burn Frequency requirements*
- ***Core Reference Orbit Definition***
  - *Frozen Orbit Elements: mean sma=6776.14 km, e = 0.0001, i = 65^0, ω = N/A, Ω=N/A*
- ***Launch and mission orbit initialization***
  - *Launch into 650km x 400km orbit*
  - *Transfer to reference orbit requires approximately 70 m/s*
- ***Orbit Maintenance***
  - *Orbit maintained nominally to +/-1 km of mean semimajor axis*
  - *Orbit maintenance ΔV depends on ballistic property (orbit average area / mass)*
  - *Developed one-burn and two-burn solutions*
  - *Using July 2005 Schatten predictions (significant decrease of the solar flux maximum value from 2004 predictions), a **5-year** GPM Lifetime analysis was run:*
    - *Initial Mass of 2880 kg and drag Area varying with beta angle profile (Average of 14.2 m^2)*
    - *Minimum of 6 days between maneuvers*
    - *Total delta-V of 161m/s with DV maneuvers of about 1 m/s*
    - *Altitude range of 397.9 km - 418.9 km*

Operations Concept

- ***Mission-level operations concept describes high-level interaction among elements***
  - *Core spacecraft*
  - *Constellation spacecraft*
  - *Mission Operations System*
  - *Precipitation processing system*
  - *Ground Validation System*
  - *Instruments*

- ***General***
  - *NASA spacecraft use TDRSS as primary communication link*
  - *Spacecraft provided by GPM partners shall deliver data as available*
  - *Collection of NASA and partner spacecraft measuring precipitation with a revisit about every 3 hours*
  - *PPS interfaces with partner data sources and the GPM science team*

Operations Concept

- ***Core Spacecraft***
  - *Carries DPR and GMI*
  - *Provides reference standard for other constellation radiometers*
  - *Makes PSD and latent heat measurements*
  - *Launches on H2A-202*
  - *Downlinks science data continuously via TDRSS-MA*
  - *Propulsion for orbit maintenance*
  - *Design for demise*
- ***Constellation Spacecraft***
  - *Carries only a radiometer (GMI)*
  - *Enhances coverage provided by partners ⇒ improves sampling*
  - *Uses TDRSS-MA continuously*
- ***Mission Operations System***
  - *Controls the spacecraft*
  - *Monitors H&S*
  - *After 60 days on-orbit checkout, manned 8 hrs, 5 days/week*

Operations Concept

- ***Precipitation Processing System***
  - *Ingests data streams from core, constellation, and partner spacecraft (up to 8 Total)*
  - *Ingests ancillary data (such as IR)*
  - *Sends overpass info to GV sites*
  - *Output products*
    - *Outreach rain map via web server*
    - *3-hour products*
    - *Climate products*
- ***Ground Validation System***
  - *Collects data and produces algorithms needed to characterize errors*
  - *Provides products to Science Team on a regular basis*
  - *Runs targeted campaigns to resolve specific issues in the precipitation retrieval algorithms*
- ***More detailed operation of each element will be described by element engineers***
- ***Draft Mission and Core Spacecraft Operations Concept documents***

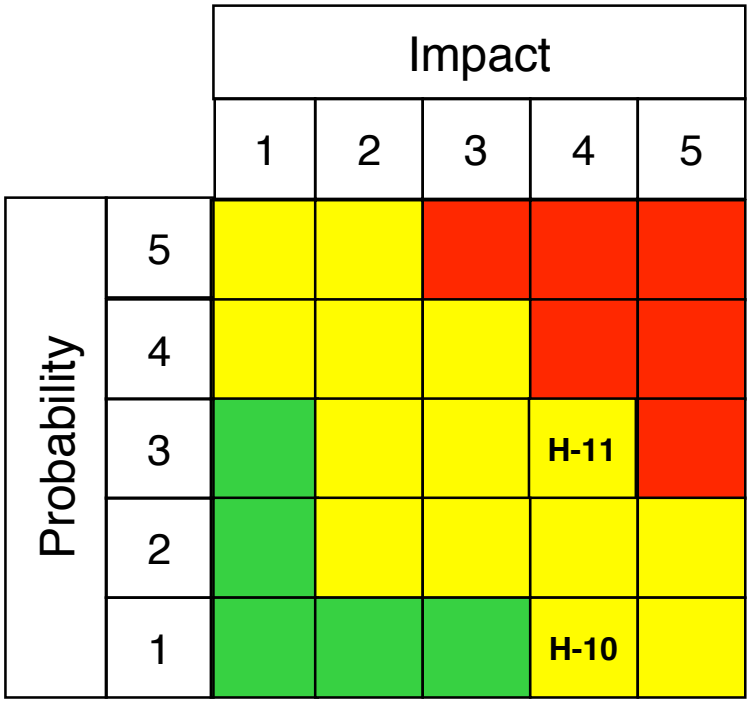
Remaining Trades

- ***Select Avionics Vendor***
  - *Complete 3Q FY06*
- ***Finalizing constellation spacecraft orbit***
  - *Complete 2Q FY06, prior to IMDC Study*
- ***Finalizing constellation spacecraft launch vehicle***
  - *Re-examine after IMDC study in April '06*
- ***GMI Thermal/Mechanical Interface***
  - *Isolate for ease of design/test/integration*
  - *Complete 3Q FY06*
- ***GMI RWA***
  - *Eliminate and treat as disturbance to Spacecraft GNC*
    - *Complete 3Q FY06*
- ***Pointing/Alignment/Geolocation***
  - *Refine and baseline budgets*
  - *Structural Distortion/Jitter analysis*
- ***Contamination Plan by PDR***
- ***Reliability Analysis - Preliminary PRA/FTA by PDR***
- ***I&T***
  - *Verification Planning*
  - *EMI/Thermal Vacuum*
  - *Simulator Definition*

Risk Title

H-10 Launch Vehicle Mass Allocation

H-11 Mission Critical Telemetry



Summary

- ***Mission Architecture has been validated to the Operations Concept***
- ***Technical Resource Budgets have been established***
- ***Identified Risks are being managed***

Agenda

Day 1 - December 6, 2005
Location: NASA GSFC B16W-N76/80

Time	Section	Event	Presenter
8:30 AM		Logistics & Announcements	Durning
8:35 AM	1	Introduction	Durning/Ho
8:45 AM		Charge to Review Team/RIDs: Purpose & Review Criteria	Ho
8:55 AM		HQ Overview	Neeck
9:10 AM	2	GPM Mission Overview	Durning
9:55 AM	3	Science Requirements	Hou
10:25 AM		**Break**	
10:40 AM	4	Mission Requirements	Bundas
11:10 AM	5	Mission Architecture	Bundas
11:55 AM		**Lunch**	
12:55 PM	6	Systems Engineering Processes	Bundas
1:40 PM	7	System Safety and Mission Assurance	Toutsi
1:55 PM	8	External Interfaces	Hwang
2:10 PM	9	Dual Precipitation Radar (DPR) Overview/Requirements	Woodall
2:55 PM		**Break**	
3:10 PM	10	GPM Microwave Imager (GMI) Overview/Requirements	Flaming/Bidwell
4:10 PM	11	H-IIA Launch Vehicle	Woodall
4:30 PM		Review Team Caucus	
4:40 PM		**End of Day 1**	